CLAIMS

1. An optical element to be used for an exposure apparatus configured to illuminate a mask with an exposure light beam for transferring a pattern on the mask onto a substrate through a projection optical system and to interpose a given liquid in a space between a surface of the substrate and the projection optical system, the optical element comprising:

a first anti-dissolution member provided on a surface of a transmissive optical element on the substrate's side of the projection optical system.

2. The optical element according to claim 1,

wherein the first anti-dissolution member comprises a single-layer film having a protective function to protect the optical element against the liquid.

3. The optical element according to claim 2,

wherein the single-layer film has solubility to pure water equal to or below 1.0×10^{-7} grams per hundred grams of water.

4. The optical element according to claim 1,

wherein the first anti-dissolution member comprises a multilayer film having a protective function to protect the optical element against the liquid and an anti-reflection function to prevent reflection of the exposure light beam.

5. The optical element according to claim 4,

wherein the multilayer film at least comprises a layer having solubility to pure water equal to or below 1.0×10^{-7} grams per hundred grams of water as the outermost layer, and

mean reflectance of the multilayer film is equal to or below 2% when an exit angle of the exposure light beam is set to 50 degrees.

6. The optical element according to claim 4,

wherein the multilayer film comprises n layers, n being an integer,

when the layers are defined sequentially as a first layer, a second layer, and so forth to an n-th layer being the outermost layer, an odd-numbered layer has a higher refractive index than a refractive index of any of the adjacent optical element and an adjacent even-numbered layer, and

the first to the n-th layers have the anti-reflection function as a whole.

7. The optical element according to claim 4,

wherein the multilayer film comprises n layers, n being an integer,

when the layers are defined sequentially as a first layer, a second layer, and so forth to an n-th layer being the outermost layer, an odd-numbered layer has a lower refractive index than a refractive index of any of the adjacent optical element and an adjacent even-numbered

layer, and

the first to the n-th layers have the anti-reflection function as a whole.

8. The optical element according to claim 1,

wherein the first anti-dissolution member is made of at least one selected from the group consisting of MgF_2, LaF_3, SrF_2, YF_3, LuF_3, HfF_4, NdF_3, GdF_3, YbF_3, DyF_3, AlF_3, Na_3AlF_6, $5NaF \cdot 3AlF_3$, Al_2O_3, SiO_2, TiO_2, MgO, HfO_2, Cr_2O_3, ZrO_2, Ta_2O_5, and Nb_2O_5.

9. The optical element according to claim 4,

wherein the multilayer film includes n layers, n being an integer, and has a layer structure, which is expressed as first layer/ second layer/ other successive layers / n-th layer, of one selected from the group consisting of

(i) LaF_3/MgF_2,

(ii) MgF_2/SiO_2,

(iii) $MgF_2/SiO_2/SiO_2$,

(iv) $LaF_3/MgF_2/SiO_2$,

(v) $LaF_3/MgF_2/Al_2O_3$,

(vi) $LaF_3/MgF_2/Al_2O_3/SiO_2$,

(vii) $LaF_3/MgF_2/LaF_3/MgF_2$,

(viii) $LaF_3/MgF_2/LaF_3/SiO_2$,

(ix) $LaF_3/MgF_2/LaF_3/MgF_2/SiO_2$, and

(x) $LaF_3/MgF_2/LaF_3/Al_2O_3/SiO_2$.

10. The optical element according to claim 1,

wherein the first anti-dissolution member is formed by at least one film forming method selected from the group consisting of a vacuum vapor deposition method, an ion beam assisted vapor deposition method, a gas cluster ion beam assisted vapor deposition method, an ion plating method, an ion beam sputtering method, a magnetron sputtering method, a bias sputtering method, an electron cyclotron resonance sputtering method, a radio frequency sputtering method, a thermal chemical vapor deposition method, a plasma chemical vapor deposition method, and an optical chemical vapor deposition method.

11. The optical element according to claim 1,

wherein the first anti-dissolution member comprises a film made of an oxide, the film being formed by a wet film forming method.

12. The optical element according to claim 4,

wherein the multilayer film comprises:

a first film formed by a dry film forming method; and

a second film made of an oxide formed by a wet film forming method.

13. The optical element according to claim 4,

wherein the multilayer film at least comprises a SiO_2 film formed by a wet film forming method as the outermost layer.

14. The optical element according to claim 13, further

comprising:

a SiO_2 film formed by a dry film forming method, which is to be provided on the optical element's side of the SiO_2 film formed by the wet film forming method.

15. The optical element according to claim 1,

wherein the first anti-dissolution member comprises a thin plate having a protective function to protect the optical element against the liquid and an anti-reflection function to prevent reflection of the exposure light beam,

wherein the thin plate is detachably joined to a surface of the optical element.

16. The optical element according to claim 15,

wherein the thin plate is joined to the surface of the optical element by optical contact, and

mean reflectance of the thin plate is equal to or below 2% when an exit angle of the exposure light beam is set to 50 degrees.

17. The optical element according to claim 15,

wherein the thin plate is made of at least one selected from the group consisting of a fluoride, an oxide, and resin.

18. The optical element according to claim 15,

wherein the thin plate is at least one selected from the group consisting of a fused silica thin plate, a magnesium fluoride thin plate, a calcium fluoride thin plate, and a polytetrafluoroethylene thin plate.

19. The optical element according to claim 1, further comprising:

a second anti-dissolution member formed on a side surface of the transmissive optical element on the substrate's side of the projection optical system.

20. The optical element according to claim 19,

wherein each of the first anti-dissolution member and the second anti-dissolution member comprises a film formed by use of an identical material.

21. The optical element according to claim 20,

wherein the film formed by use of the identical material is formed by a wet film forming method.

22. The optical element according to claim 20,

wherein the identical material is any of MgF_2 and SiO_2.

23. The optical element according to claim 19,

wherein the first anti-dissolution member comprises a hydrophilic anti-dissolution film, and

the second anti-dissolution member comprises a hydrophobic anti-dissolution film.

24. The optical element according to claim 19,

wherein the second anti-dissolution member comprises a metal anti-dissolution film having a protective function to protect the optical element against the liquid.

25. The optical element according to claim 24,

wherein the second anti-dissolution member further comprises an adhesion reinforcing film formed between the side surface of the optical element and the metal anti-dissolution film.

26. The optical element according to claim 24,

wherein the second anti-dissolution member further comprises a protective film for the metal anti-dissolution film, the protective film being formed on a surface of the metal anti-dissolution film.

27. The optical element according to claim 24,

wherein the metal anti-dissolution film has solubility to pure water equal to or below 2 ppt and packing density equal to or above 95%.

28. The optical element according to claim 24,

wherein the metal anti-dissolution film is made of at least one selected from the group consisting of Au, Pt, Ag, Ni, Ta, W, Pd, Mo, Ti, and Cr.

29. The optical element according to claim 25,

wherein the adhesion reinforcing film is made of at least one selected from the group consisting of Ta and Cr.

30. The optical element according to claim 26,

wherein the protective film for the metal anti-dissolution film is made of at least one selected from the group consisting of SiO_2, Y_2O_3, Nd_2F_3, Cr_2O_3, Ta_2O_5, Nb_2O_5, TiO_2, ZrO_2, HfO_2, and La_2O_3.

31. The optical element according to claim 19,

wherein the second anti-dissolution member includes a light-shielding film.

32. The optical element according to claim 31,

wherein the light-shielding film is formed of any of a metal film and a metal oxide film.

33. The optical element according to claim 32,

wherein the metal film is made of at least one selected from the group consisting of Au, Pt, Ag, Ni, Ta, W, Pd, Mo, Ti, and Cr, and

the metal oxide film is made of at least one selected from the group consisting of ZrO_2, HfO_2, TiO_2, Ta_2O_5, SiO, and Cr_2O_3.

34. The optical element according to claim 1, further comprising:

an optical member joined to a surface of the optical element by optical contact through the first anti-dissolution member.

35. The optical element according to claim 34,

wherein the first anti-dissolution member is a film made of SiO_2, and

the optical member is a member made of silica glass.

36. The optical element according to claim 1,

wherein the exposure light beam is an ArF laser beam,

the optical element is an element made of calcium fluoride, and

crystal orientation of the surface of the optical

element is defined as a (111) plane.

37. An optical element to be used for an exposure apparatus configured to illuminate a mask with an exposure light beam for transferring a pattern on the mask onto a substrate through a projection optical system and to interpose a given liquid in a space between a surface of the substrate and the projection optical system, the optical element comprising:

a light-shielding film provided on a side surface of a transmissive optical element on the substrate's side of the projection optical system.

38. The optical element according to claim 37,

wherein the light-shielding film is formed of any of a metal film and a metal oxide film.

39. The optical element according to claim 38,

wherein the metal film is made of at least one selected from the group consisting of Au, Pt, Ag, Ni, Ta, W, Pd, Mo, Ti, and Cr, and

the metal oxide film is made of at least one selected from the group consisting of ZrO_2, HfO_2, TiO_2, Ta_2O_5, SiO, and Cr_2O_3.

40. An exposure apparatus configured to illuminate a mask with an exposure light beam for transferring a pattern on the mask onto a substrate through a projection optical system and to interpose a given liquid in a space between a surface of the substrate and the projection optical

system, the exposure apparatus comprising:

a first anti-dissolution member provided on a surface of a transmissive optical element on the substrate's side of the projection optical system.

41. The exposure apparatus according to claim 40,

wherein the first anti-dissolution member comprises a single-layer film having a protective function to protect the optical element against the liquid.

42. The exposure apparatus according to claim 40,

wherein the first anti-dissolution member comprises a multilayer film having a protective function to protect the optical element against the liquid and an anti-reflection function to prevent reflection of the exposure light beam.

43. The exposure apparatus according to claim 40,

wherein the first anti-dissolution member is made of at least one selected from the group consisting of MgF_2, LaF_3, SrF_2, YF_3, LuF_3, HfF_4, NdF_3, GdF_3, YbF_3, DyF_3, AlF_3, Na_3AlF_6, $5NaF \cdot 3AlF_3$, Al_2O_3, SiO_2, TiO_2, MgO, HfO_2, Cr_2O_3, ZrO_2, Ta_2O_5, and Nb_2O_5.

44. The exposure apparatus according to the claim 42,

wherein the multilayer film comprises n layers, n being an integer, and has a layer structure, which is expressed as first layer/ second layer/ other successive layers / n-th layer, of one selected from the group consisting of

(i) LaF_3/MgF_2,

(ii) MgF_2/SiO_2,

(iii) $MgF_2/SiO_2/SiO_2$,

(iv) $LaF_3/MgF_2/SiO_2$,

(v) $LaF_3/MgF_2/Al_2O_3$,

(vi) $LaF_3/MgF_2/Al_2O_3/SiO_2$,

(vii) $LaF_3/MgF_2/LaF_3/MgF_2$,

(viii) $LaF_3/MgF_2/LaF_3/SiO_2$,

(ix) $LaF_3/MgF_2/LaF_3/MgF_2/SiO_2$, and

(x) $LaF_3/MgF_2/LaF_3/Al_2O_3/SiO_2$.

45. The exposure apparatus according to claim 40,

wherein the first anti-dissolution member comprises a film made of an oxide formed by a wet film forming method.

46. The exposure apparatus according to claim 42,

wherein the multilayer film comprises:

a first film formed by a dry film forming method; and

a second film made of an oxide, which is formed by a wet film forming method.

47. The exposure apparatus according to claim 40,

wherein the first anti-dissolution member comprises a thin plate having a protective function to protect the optical element against the liquid and an anti-reflection function to prevent reflection of the exposure light beam, and

the thin plate is detachably joined to a surface of

the optical element.

48. The exposure apparatus according to claim 40, further comprising:

a second anti-dissolution member on a side surface of the transmissive optical element on the substrate's side of the projection optical system.

49. The exposure apparatus according to claim 48,

wherein each of the first anti-dissolution member and the second anti-dissolution member comprises a film formed by use of an identical material.

50. The exposure apparatus according to claim 48,

wherein the second anti-dissolution member comprises a metal anti-dissolution film having a protective function to protect the optical element against the liquid.

51. The exposure apparatus according to claim 50,

wherein the second anti-dissolution member further comprises an adhesion reinforcing film formed between the side surface of the optical element and the metal anti-dissolution film.

52. The exposure apparatus according to claim 50,

wherein the second anti-dissolution member further comprises a protective film for the metal anti-dissolution film, and

the protective film is formed on a surface of the metal anti-dissolution film.

53. The exposure apparatus according to claim 50,

wherein the metal anti-dissolution film is made of at least one selected from the group consisting of Au, Pt, Ag, Ni, Ta, W, Pd, Mo, Ti, and Cr.

54. The exposure apparatus according to claim 52,

wherein the protective film for the metal anti-dissolution film is made of at least one selected from the group consisting of SiO_2, Y_2O_3, Nd_2F_3, Cr_2O_3, Ta_2O_5, Nb_2O_5, TiO_2, ZrO_2, HfO_2, and La_2O_3.

55. The exposure apparatus according to claim 48,

wherein the second anti-dissolution member comprises a light-shielding film.

56. The exposure apparatus according to claim 55,

wherein the light-shielding film is formed of any of a metal film and a metal oxide film.

57. The exposure apparatus according to claim 56,

wherein the metal film is made of at least one selected from the group consisting of Au, Pt, Ag, Ni, Ta, W, Pd, Mo, Ti, and Cr, and

the metal oxide film is made of at least one selected from the group consisting of ZrO_2, HfO_2, TiO_2, Ta_2O_5, SiO, and Cr_2O_3.

58. The exposure apparatus according to claim 40, further comprising:

an optical member joined to a surface of the optical element by optical contact through the first

anti-dissolution member.

59. The exposure apparatus according to claim 40,

wherein the exposure light beam is an ArF laser beam,

the optical element is an element made of calcium fluoride, and

crystal orientation of the surface of the optical element is defined as a (111) plane.

60. An exposure apparatus configured to illuminate a mask with an exposure light beam for transferring a pattern on the mask onto a substrate through a projection optical system, and to interpose a given liquid in a space between a surface of the substrate and the projection optical system, the exposure apparatus comprising:

a light-shielding film provided on a side surface of a transmissive optical element on the substrate's side of the projection optical system.

61. The exposure apparatus according to claim 60,

wherein the light-shielding film is formed of any of a metal film and a metal oxide film.

62. The exposure apparatus according to claim 61,

wherein the metal film is made of at least one selected from the group consisting of Au, Pt, Ag, Ni, Ta, W, Pd, Mo, Ti, and Cr, and

the metal oxide film is made of at least one selected from the group consisting of ZrO_2, HfO_2, TiO_2, Ta_2O_5, SiO, and Cr_2O_3.